CHAPTER 10

PERSONAL PROTECTIVE EQUIPMENT AND CHEMICAL PROTECTIVE CLOTHING

1. **GENERAL**. When occupational safety and health hazards cannot be eliminated or reduced through engineering controls or administrative procedures, the use of personal protective equipment (PPE) is mandatory. This chapter contains guidance on the selection, effective use and care of the PPE that you may recommend for employees. This includes (1) chemical protective clothing (CPC), which encompasses gloves, aprons, coveralls, pants, jackets, and boots, and (2) eye/face protection, including goggles, glasses and face shields. Respiratory protection is covered in Chapter 9 of this manual; hearing protection is addressed in Chapter 4. The guidance in this chapter does not apply to equipment intended specifically for chemical/biological warfare defence.

2. **RESPONSIBILITIES**. Per Chapter 20 of Reference 10-1, the Commanding Officer/Officer-in-Charge is responsible for ensuring that PPE and CPC is available, maintained and properly used by employees. Personnel must be trained in the selection, use, inspection, and care of required equipment. Industrial hygienists should determine the need for PPE and provide recommendations regarding its selection during routine industrial hygiene surveys and upon request from customer commands.

3. **USE AND SELECTION OF PPE**.

a. Use PPE when:

(1) Other control measures are not adequate. CAUTION: PPE should NEVER be used as a substitute for engineering or administrative controls. PPE is always considered the LAST LINE OF DEFENSE.

(2) The nature of hazard or degree of exposure cannot be determined, such as during emergency response (spills, etc.) or confined space entry.

(3) Navy Occupational Safety and Health exposure limits are exceeded.

b. PPE is selected based on the nature of the hazard, route(s) of entry for the stressors and the degree of protection

that a particular piece of equipment affords under varying conditions.

c. If there are selection options available, additional considerations may include user acceptability and ease of using the PPE.

4. **EYE/FACE PROTECTION**. References 10-2 and 10-3 address design, construction, testing and use of eye and face protection. Reference 10-2 lists appropriate eye protection for specific work operations and tasks. Depending on the operation, faceshields/helmets may be required in addition to safety glasses/goggles.

a. Safety glasses protect eyes from foreign bodies. Prescription safety lenses are available. Safety glasses with sideshields provide increased protection.

b. Faceshields protect the whole face from foreign debris and liquid splashes. However, liquid may pass around the edges of the faceshield and still contact the wearer's face.

c. Flexible goggles give frontal and side protection and will fit over regular glasses. The ventilation openings are drilled straight through the goggle and will allow easy passage of liquids.

d. Chemical splash goggles with covered ventilation openings protect eyes against sprays and splashes of chemicals.

e. Welding helmets protect the eyes and face against arc rays, weld sparks and splatters. Welding goggles protect eyes only. In some instances ultraviolet radiation has been reflected off workroom surfaces behind the worker and inside the helmet from the rear. New technology welding helmets are available with lenses that almost instantaneously darken when an arc is struck.

5. **CHEMICAL PROTECTIVE CLOTHING (CPC)**.

a. CPC is a subset of PPE and includes all items of protective clothing whose main purpose is to provide skin protection against chemical, physical, and/or biological hazards. CPC includes gloves, aprons, coveralls, jackets, pants and boots.

b. Many stressors pose "invisible" hazards and offer no warning properties. Unfortunately, no single combination of protective equipment and clothing can protect against all hazards. Therefore, CPC should be used with other protective methods, such as engineering controls, to limit exposure.

c. Using CPC can itself create hazards to the wearer, such as heat stress, physical and psychological stress, impaired vision and restricted mobility and communication. In general, the greater the level of CPC, the greater the associated risks. For any given situation, CPC should be selected that provides an adequate level of protection. Over-protection may cause its own hazardous situation and should be avoided.

d. CPC must be worn whenever there are potential hazards arising from direct exposure. Some examples include emergency response; equipment leaks or failures; chemical baths and other treatment processes; hazardous waste site clean up and disposal; asbestos removal and other particulate operations; and pesticide application.

6. **CPC CLASSIFICATION**. CPC can be classified by:

a. Design - Categorizing CPC by design is a means of describing what areas of the body the clothing item is intended to protect. This includes gloves, boots, coveralls, aprons and full body suits. References 10-4 and 10-5 have more detailed information.

b. Performance - CPC may be classified by its ability to provide protection. This may be further divided into particulate protection, liquid or splash protection, vapor protection, and/or protection against heat/cold. Combinations of the physical and chemical attributes of the stressor(s) must be considered.

c. Service life - This is an end user decision depending on the cost and risks associated with clothing decontamination and reuse. CPC may be labeled as reusable (multiple wearings) or disposable (one-time use). Disposable clothing is generally lightweight and inexpensive. Reusable clothing is often more rugged, but also more costly.

(1) Extensive contamination of any garment may render it disposable. The basis of this classification really depends on the cost involved in purchasing, maintaining, and reusing CPC versus the alternative of disposal following exposure.

(2) The key assumption in this determination is that the garment will provide an effective barrier during and after exposure and can be effectively decontaminated.

7. **WORKSITE CHARACTERIZATION**.

a. As required by Reference 10-3, the importance of characterizing the workplace or process before recommending appropriate CPC cannot be over-emphasized. This may be done as a

plan review before the first piece of equipment is installed, as a process change or when there is a change in the use of hazardous materials. It may even come after worker complaints. References 10-4 through 10-9 provide further information on worksite characterization.

b. Physical conditions of the worksite - Chemical exposures can happen indoors or outdoors. The environment may be hot, cold or moderate. The exposure site may present physical hazards. Chemical handling activities may involve entering confined spaces, heavy lifting, climbing a ladder or crawling on the ground. The choice of ensemble components must allow for adequate mobility and dexterity.

c. Chemical hazard - Chemicals may be toxic, corrosive, flammable, reactive, oxygen deficient or any combination of these. Consider the following: What is the concentration of the chemical in use? What are the consequences of skin exposure? Are there known significant toxic doses, chronic hazards or reported fatalities by skin absorption? Is the chemical an allergic sensitizer?

d. Physical condition of the hazard:

(1) Solids or particulates - Porous CPC minimizes heat stress, but must also be able to block particulates.

(2) Liquids and/or vapors - CPC material must be non-porous for protection against liquids. Breathable (i.e., microporous) materials may be used for splash protection.

e. Duration of exposure - The protective qualities of ensemble components may be limited to certain exposure levels (i.e., material chemical resistance). Assume the worst case exposure and the maximum time that CPC will be worn so that safety margins can be applied to increase the protection available to the worker.

f. Some operations will require CPC without a site characterization. Examples include investigating hazardous material incidents, firefighting/rescue operations, spill mitigation and operations that have been fully characterized and are not expected to change despite where the operations take place.

8. **THE CPC ENSEMBLE**.

a. A variety of clothing and equipment must be available to workers to handle a broad range of chemical exposures. Further, having several sizes of CPC will help eliminate dangers from

clothing that is too loose (possible trip hazard; loss of dexterity) or too tight (loss of motion range from binding; tears in clothing).

The approach in selecting CPC must encompass an "ensemble" of clothing and equipment items that are easily integrated to provide both an appropriate level of protection and still allow one to carry out activities involving direct exposure.

b. Factors that affect the use of ensemble components include:

(1) How each item fits the integration of other ensemble components. Some ensemble components may be incompatible because of how they are worn. For example, some SCBAs may not fit in a particular chemical protective suit or may not allow acceptable mobility.

(2) The ease of interfacing ensemble components without sacrificing required performance (e.g., a poorly fitting overglove greatly reduces wearer dexterity).

(3) Limiting the number of equipment items to reduce donning time and complexity.

(4) Ensemble design or configuration alone is not sufficient to ensure adequate protection. The performance of the selected clothing or equipment must also be known.

c. Level of protection - The type of equipment used and the overall level of protection should be reevaluated periodically as the amount of information about the chemical situation or process increases, and when workers are required to do different tasks. Personnel should upgrade or downgrade their level of protection only with the concurrence with the safety officer or industrial hygienist. See References 10-5 and 10-7 for more detailed information.

9. **CHEMICAL RESISTANCE OF CPC**. The ability of CPC to act as a chemical barrier is determined by the CPC material and the method of construction. Usually, each chemical interacts with a given plastic or elastomer differently so there is a unique situation for each chemical/CPC material pair. Ideally, the chosen material(s) must be based on:

a. Permeation - the process by which a chemical moves through a material on a molecular basis.

(1) Permeation rate - usually expressed in terms of amount of chemical which passes through a given area per unit

time (g/cm^2/min). The total amount of chemical permeating a CPC material is dependent on the area exposed and the duration of exposure. For a given chemical/CPC material pair, the permeation rate decreases as the material thickness increases.

(2) Breakthrough time - the elapsed time from the initial contact of the chemical with the outside surface of the CPC material to the first detection of the chemical on the inside surface of the material. There may be situations where breakthrough times are longer in one chemical/CPC pair than another, yet the material with shorter breakthrough time is recommended because its permeation rate is very small when compared to the chemical/CPC material pair with the long breakthrough time. On the other hand, breakthrough time may be the most important criterion when the chemical is a carcinogen and no skin contact is desired.

b. Degradation - physical changes in a material as the result of a chemical/physical exposure or use. The most common observation of material degradation is discoloration, swelling, loss of physical strength, or deterioration.

c. Penetration - the gross movement of a chemical through zippers, seams, or imperfections in CPC material.

d. Chemical mixtures - can be significantly more aggressive toward materials than any single chemical alone. One chemical may pull another with it through the material; another may change the CPC material structure and allow greater diffusion of other chemicals. Very little data is available for chemical mixtures, and serious consideration must be given to deciding which CPC is selected. If clothing must be used without test data, then garments with materials having the broadest chemical resistance should be worn.

10. **PHYSICAL RESISTANCE OF CPC**. CPC garments offer a wide range of physical qualities in terms of strength, resistance to physical hazards, and operation in extreme environmental conditions. Assess a garment's physical properties by asking:

a. Will the garment resist tears, punctures, cuts, and abrasions?

b. Will the garment withstand repeated use after contamination and decontamination?

c. Is the garment flexible enough to allow end users to perform needed tasks?

d. Will the material maintain its protective integrity and flexibility under hot and cold temperature extremes?

e. Is the garment flame resistant or self-extinguishing if necessary?

f. Are garment seams constructed so they provide the same physical integrity as the garment material?

11. **SELECTION OF CPC**.

a. Selection of CPC is a complex task and must be performed by personnel with appropriate training and experience. Under all conditions, clothing should be selected by evaluating its performance characteristics against the requirements and limitations imposed by the application. Unfortunately, one must often estimate CPC performance without the benefit of test data, especially when dealing with protection for chemical mixtures. Some guiding principles for selecting CPC follow:

(1) Chemicals from the same family (alcohols, primary amines, alkanes, aldehydes, etc.) will tend to permeate a given CPC material at similar rates with similar breakthrough times.

(2) Permeation rate is inversely proportional to molecular weight within the same family.

(3) Attached groups (which increase the molecular size) tend to slow permeation relative to the simple molecule.

(4) Polar chemicals tend to permeate polar material more rapidly than non-polar chemicals and vice versa. For example, water permeates polyvinyl alcohol very quickly, but permeates rubber slowly.

(5) Also consider effects of material thickness and effects of temperature extremes.

b. Sources of selection information include:

(1) Vendor data or recommendations. The best source of current information on material compatibility should be available from the manufacturer of the selected CPC. Many vendors supply charts that show actual test data or their recommendations for specific chemicals. However, use caution when interpreting this information, particularly if vendor data are not well documented. Material recommendations must be based on data obtained from tests performed in accordance with American Society for Testing Materials (ASTM) methods. Simple ratings of "poor", "good",l

or "excellent" do not quantitate the material's performance against various chemicals.

(2) Reference 10-8 provides chemical resistance data and recommendations for eleven generic materials against over 400 chemicals. The guide is color-coded by material-chemical recommendation. The major limitation of this reference is its dependence on generic data.

(3) References 10-9 through 10-13 are excellent sources of CPC product information.

(4) NIOSH provides personal protective equipment recommendations for hazardous chemicals on their web site at http://www.cdc.gov/niosh/ncpc/ncpc1.htm entitled "Recommendations for Protective Clothing, A Companion to the NIOSH Pocket Guide to Chemical Hazards".

12. **WEARING CPC**.

a. Establish routine procedures for donning and doffing various ensemble configurations. Practice periodically.

b. Plan for providing donning and doffing assistance if ensembles are cumbersome or if solo efforts increase the possibility of ensemble damage.

c. Once equipment is donned, evaluate its fit. If the clothing is too small, it will restrict movement, increasing the likelihood of tearing the material and accelerating wearer fatigue. Clothing that is too large increases the possibility of snagging the material and may hamper the wearer's dexterity and coordination.

d. Doffing procedures should focus on preventing contaminant migration from the work site and ensuring that contaminants do not transfer to the wearer's body, to other personnel or to the environs. When necessary, doffing should be done after decontamination or in a manner to reduce contamination to the wearer. If this requires a suitably attired assistant, both wearer and assistant should avoid any direct contact with the outside surface of the clothing.

13. **DECONTAMINATION**.

a. Decontamination removes or neutralizes contaminants that have accumulated on CPC, personnel and equipment. Proper decontamination does the following:

(1) Protects end users from hazardous substances that may contaminate and eventually permeate the CPC, respiratory equipment, tools, vehicles or other equipment used at or near the hazard area.

(2) Protects the community and site personnel by minimizing the transfer of contaminants into clean areas.

b. Things to consider during decontamination procedures:

(1) Is the CPC adversely affected by the decontamination? The physical or chemical resistance may be affected by heat or chemicals used to clean the CPC.

(2) Is the decontamination process effective? There is some indication that volatile, small molecule chemicals may be successfully removed from the CPC with the use of heat. No standard method is available to determine whether a product is decontaminated.

(3) Can the decontamination process cause exposure? Any chemicals used in the process must be evaluated to ensure they do not result in unacceptable exposures, either during the decontamination process or when the CPC is reused.

c. For more detailed information on CPC decontamination, see References 10-5 through 10-7 and 10-14.

14. **PPE/CPC INSPECTION**.

a. The PPE user must take all necessary steps to ensure that the protective ensemble will perform as expected. Emergencies are not the right time to discover problems! Following a standard program for inspecting protective equipment and realizing its limitations are the best ways to avoid exposure during PPE use. Reference 10-4 provides guidelines for inspecting CPC. Appendix A of Reference 10-6 lists procedures for inspecting fully encapsulating suits. Additional inspection information may be available from the PPE manufacturer.

b. An effective CPC inspection program features:

(1) Inspection and operational testing of equipment as received from the factory or distributor;

(2) Inspection of equipment as it is selected for a particular chemical operation;

(3) Inspection of equipment after use or training and prior to maintenance;

(4) Periodic inspection of stored equipment; and

(5) Periodic inspection when questions arise about the appropriateness of the selected equipment, or when problems with similar equipment are discovered.

15. **STORAGE**. All PPE must be stored properly to prevent damage or malfunction from exposure to dust, moisture, sunlight, damaging chemicals, extreme temperatures, and impact. Some guidelines for storage include:

a. Potentially contaminated clothing or equipment should be stored separately from street clothing and unused PPE.

b. Potentially contaminated PPE should be stored in a well-ventilated area, with good air flow around each item.

c. Different types and materials of CPC should be stored separately to prevent issuing the wrong material by mistake (i.e., many glove materials are black and cannot be identified by appearance alone).

d. To help avoid PPE failure from improper storage, fold or hang clothing according to manufacturer instructions.

16. **HEAT STRESS**.

a. Wearing full body PPE puts the wearer at considerable risk for heat stress. This can result in health effects ranging from transient heat fatigue to serious illness or death.

b. Heat stress is caused by several interacting factors, including environmental conditions, type of protective ensemble worn, work activity required and physical condition of the wearer.

c. When selecting protective clothing and equipment, each item's benefit should be carefully evaluated for its potential for increasing the risk of heat stress. For example, choose a lighter, less insulating suit if it can be worn without sacrificing protection. For more information on heat stress, consult Reference 10-15.

17. **TRAINING**. Training is required by Reference 10-3 and must be provided to each employee who is required to wear PPE.

a. Training should include at least the following:

(1) When to wear PPE;

(2) What PPE to wear;

(3) How to don, doff, adjust, and wear PPE;

(4) What are the capabilities and limitations of the PPE;

(5) How to properly maintain PPE; and

(6) When and how to dispose of PPE.

b. Employees must demonstrate knowledge of the training specified above and the ability to use PPE properly before being allowed to perform work requiring the use of PPE.

c. Training is required annually or whenever any of the following situations occur:

(1) Workplace operations change such that previous PPE or training is obsolete.

(2) Employees demonstrate that they do not understand the training they received.

d. Written records of training must include the employees' name, date(s) of training, and training topics.

e. Depending on the actual use or application of the PPE/CPC items, consult References 10-3, 10-6 and 10-16.

18. **REFERENCES**.

10-1 OPNAVINST 5100.23 Series, Chapter 20, *Personal Protective Equipment.*

10-2 ANSI. *Practice for Occupational and Educational Eye and Face Protection* (includes supplement and partial revision Z87.1a-1991). ANSI Z87.1-1989. New York, NY: American National Standards Institute. 1989.

10-3 Code of Federal Regulations, Title 29, Part 1910, Subpart I, Sections 132-138. *Personal Protective Equipment.*

10-4 OSHA. *Occupational Safety and Health Administration Technical Manual*, Section VII, Chapter 1, Chemical Protective Clothing. OSHA Instruction TED 1.15. Washington, D.C.: U.S. Department of Labor. 1995.

10-5 Johnson, J. S. and Anderson, K. J., ed.: *Chemical Protective Clothing*. Vol. 1. Akron: American Industrial Hygiene Association. 1990.

10-6 Code of Federal Regulations, Title 29, Part 1910.120. *Hazardous Waste Operations and Emergency Response.*

10-7 Barker, R. L and Colette, G. C., ed.: *Performance of Protective Clothing.* A Symposium Sponsored by ASTM Committee F-23. July 16-20, 1984. Raleigh, NC. ASTM Special Publication 900. 1986. pp. 207-213.

10-8 Forsberg, K. and Mansdorf, S. Z.: *Quick Selection Guide to Chemical Protective Clothing*. 1st Edition. New York: Van Nostrand Reinhold. 1989.

10-9 NIOSH. *A Guide for Evaluating the Performance of Chemical Protective Clothing (CPC).* DHHS (NIOSH) Pub. No. 90-109. Cincinnati, OH: U.S. Department of Health and Human Services. 1990.

10-10 Schwope, A. D., Costas, P. P., Jackson, J. O., Stull, J. O., and Weitzman, D. J., ed., *Guidelines for Selection of Chemical Protective Clothing.* 3rd ed., Vol. 1. Cincinnati: ACGIH, 1987.

10-11 Johnson, J. S. and Anderson, K. J., ed.: *Chemical Protective Clothing*, Vol. 2, Product and Performance Information. Akron, OH: American Industrial Hygiene Association, 1990.

10-12 Forsberg, K. and Keith L. H.: *Chemical Protective Clothing Permeation and Degradation Database.* Boca Raton: Lewis Publishers. 1993.

10-13 Keith L. H.: *National Toxicology Programs's Gloves+. An Expert System for Selecting Protective Clothing Against Hazardous Chemicals*. Boca Raton: Lewis Publishers. 1992.

10-14 Perkins, J. L.: *Decontamination of Protective Clothing*. Appl. Occup. Environ. Hyg. 6(1):29-35 (1991).

10-15 OSHA. Occupational Safety and Health Administration Technical Manual, Section II, Chapter 4, Heat Stress. OSHA Instruction TED 1.15. Washington, D.C.: U.S. Department of Labor. 1995.

10-16 Code of Federal Regulations, Title 29, Part 1910.1200. *Hazard Communication*.

19. **OTHER USEFUL REFERENCES NOT CITED IN THIS CHAPTER**.

ASTM. *Chemical Protective Clothing Performance in Chemical Emergency Response*, edited by J. L. Perkins and J. O. Stull. Special Technical Publication (STP) 1037. Philadelphia, PA: American Society for Testing and Materials. 1989.

ASTM. *Standard Test Method for Resistance of Protective Clothing Materials to Permeation by Liquids or Gases Under Conditions of Continuous Contact.* Designation F739-91. Philadelphia, PA. 1991.

National Institute for Occupational Safety and Health (NIOSH)/Occupational Safety and Health Administration (OSHA)/ U.S. Coast Guard (USCG)/ U.S. Environmental Protection Agency (EPA). *Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities*. DHHS (NIOSH) Pub. No. 85-115. Washington, DC: U.S. Government Printing Office. 1985.